The AT Effect: How Disability Affects the Perceived Social Acceptability of Head-Mounted Display Use

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ABSTRACT
Wearable computing devices offer new possibilities to increase accessibility and independence for individuals with disabilities. However, the adoption of such devices may be influenced by social factors, and useful devices may not be adopted if they are considered inappropriate to use. While public policy may adapt to support accommodations for assistive technology, emerging technologies may be unfamiliar or unaccepted by bystanders. We surveyed 1200 individuals about the use of a head-mounted display in a public setting, examining how information about the user's disability affected judgments of the social acceptability of the scenario. Our findings reveal that observers considered head-mounted display use more socially acceptable if the device was being used to support a person with a disability.

Author Keywords
Wearable Computing; Social Perceptions; Assistive Technology.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; K.4.2. Social issues: assistive technologies for persons with disabilities.

INTRODUCTION
Wearable computing devices such as head-mounted displays offer new opportunities for individuals with disabilities. Recent examples span a range of new technologies, from hands-free computer access for users with motor impairments [2, 20, 21] to navigation support [9] and translation of visual information for blind users [23].

While these wearable technologies have the potential to provide improved accessibility by increasing ease of access, using assistive technology in public can garner unwanted attention [14, 29]. Similarly, using a wearable computing device in public can also draw unwanted attention from bystanders [6, 25, 26, 27]. In extreme cases, negative reactions to the use of wearable computers can cause these devices to be scrutinized or even banned. For example, privacy concerns surrounding Google Glass [10] and its ability to record individuals without their consent resulted in the prohibition of Glass in some public establishments [11].

Figure 1. Participants judged the social acceptability of a video scenario showing an actress using a head-mounted display in public. We varied information about the actress's disability by manipulating the video description and the actress's appearance. Left: Actress wearing Google Glass. Right: Actress wearing Google Glass with eye shades.

A person with a disability who wishes to use a new assistive technology (AT) device must therefore balance their need for the device with the social challenges of using conspicuous technology in public. In some cases, the stress of using an AT device in public may cause individuals to forgo using a device that would otherwise help them [14, 29]. While prior research has shown that the use of some assistive technologies can cause social stress [17], this stress may be lessened when the general population becomes familiar with an accommodation. Few people question the appropriateness of parking spaces designated for people with disabilities or the use of a service animal. In fact, sometimes these accommodations can generate positive social effects. For example, people with service dogs receive more substantial social acknowledgments, including smiles, greetings, and conversations when navigating in public [19], however, these individuals may still experience challenges if required to deal with someone unfamiliar with the norms surrounding use of service animals [33].

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In this paper, we explore individuals' responses to the use of a new assistive technology (a head-mounted display or HMD) in a social setting. While HMDs have existed for many years, they have only recently entered the public spotlight through products such as Google Glass. Many individuals may not know how these technologies may be used or even whether they may be used by someone with a disability. Furthermore, the ability of HMDs such as Google Glass to make surreptitious recordings may generate increased concern about their use in public [6]. Thus, exploring the use of HMDs for accessibility presents a rare opportunity to observe reactions to an emerging AT form factor before the technology and surrounding policies have been fully established [12].

We conducted a study that solicited responses from "bystanders" who observed an individual using an HMD in a public setting. We recruited over 1200 participants via Amazon Mechanical Turk [1]. All participants were located in the United States. Participants watched a video scenario in which an actress used Google Glass at a public bus stop (Figure 1). Participants received differing information about what tasks the actress performed with the device and whether the actress had a disability. We manipulated information about the actress's disability both by changing the text description of the video as well as changing the appearance of the actress (providing her with dark glasses and a mobility cane to appear as someone with a vision impairment). Participants provided feedback about the usefulness of the HMD and the appropriateness of using the device in a public setting.

Our findings reveal that participants found use of the HMD to be more acceptable when the user had a disability than when they did not, and that use of the HMD for accessibility tasks could override some of the negative perceptions of the device in general. These findings show how bystanders may react to seeing a new and unfamiliar AT device, and may provide useful insights for developing appropriate social norms and policy around emerging forms of assistive technology.

RELATED WORK

The recent availability of consumer-grade HMDs has sparked an interest in understanding how these devices can support accessibility. We review applications of HMDs for accessibility, research on social perceptions of wearable device interaction, and social considerations of AT usage.

HMDs for Accessibility

HMDs can provide several benefits for accessibility, such as providing always-available visual feedback, reducing the need for manual interaction with a computing device, and enabling capture of the environment through on-device cameras. Prior applications of HMDs for accessibility include mobile user interfaces for individuals with motor impairments [2, 20, 21] and older adults [18], spatial-audio-based navigation for blind people [9], visualization of environmental sounds for individuals with hearing impairments [13], conversational cueing for people with communication disabilities [34], and augmented reality feedback to support individuals with color blindness [31]. While these projects have shown the potential uses of HMDs for improving accessibility, few studies have explored the use of wearable AT in a social context.

Social Perceptions of Wearable Computing

Interaction with wearable computing devices presents its own set of social challenges. These challenges often involve the appearance and location of the device, the form of interaction with the device, and bystanders' lack of familiarity with wearable computing devices. Prior work has explored how the design of wearable computing devices and their interaction methods can affect the user's own comfort [8, 15] as well as bystanders' perceptions [25, 26, 27, 32]. Concerns about the social effects of using a wearable computing device may be compounded if the user has a disability, as interaction with the device may both draw unwanted attention and reveal details about that person's disability [35]. Oh and Findlater evaluated alternative on-body input scenarios for individuals with visual impairments and found that users preferred discreet input areas, such as the hands, and favored the social acceptability of the action over ease of use or physical comfort [22].

A second concern related to the use of wearable computers in public is that of recording and privacy. Many HMDs feature cameras, and these cameras can be used for assistive purposes, such as serving as a memory aid [28] or supporting independent navigation [9]. However, the ability of HMDs to capture images at any time may have negative social effects, as bystanders may not wish to be recorded without their permission or awareness [6]. Our present work explores several social considerations related to the use of a wearable AT device, including how the user interacts with the device and whether the device can record video.

Social Aspects of Assistive Technology Usage

Choosing to use an AT device involves considering both the functionality of the device as well as the social implications of using it. The "social weight" of an AT device can drastically impact adoption and use of that device [5]. Parette and Scherer identified several social factors that influenced adoption of AT, including aesthetics, gender/age appropriateness, and social acceptability [24]. Social considerations can affect use of both new and more traditional AT: for example, some individuals with vision impairments may choose to forgo their white cane in order to avoid drawing attention [29]. Several recent studies have shown that individuals with disabilities often prefer to use mainstream rather than specialized computing devices, in part due to social factors [14, 29]. On the other hand, use of accommodations such as a service dog can result in positive social outcomes [19]. Using new forms of AT can create additional problems, as bystanders may be confused or curious about the device, and because policies to support use of AT often lag behind technical innovation [16].

Recently, Kirkham [16] explored concerns and priorities related to creating policies to support use of wearable computing devices, including HMDs, for accessibility. McNaney et al. [21], conducted a user study that explored the use of HMDs for individuals with Parkinson's disease, finding that there existed a tension between the functional benefits of the device and the wearer's concern about social issues. Our work contributes a new perspective to this emerging research area by exploring perceptions of bystanders regarding use of wearable AT in a public place.

METHOD

Our study explores the social perceptions of third-party bystanders as they view a person interacting with an HMD in a simulated public setting, and how information about the user's activity or disability would affect that perception. We recruited over 1200 US-based participants via Amazon Mechanical Turk, who watched a video scenario of public HMD use and completed a questionnaire.

Participants

We recruited participants (ages 18 and older) using Mechanical Turk. We limited our recruitment to individuals from the United States to collect a consistent set of cultural responses, as cultural norms and attitudes may differ across countries. We recruited Mechanical Turk Master workers (a classification granted by Amazon based on prior performance) as the first 150 participants, but found that recruiting Master workers was extremely time consuming and did not substantially affect response quality; following this, we recruited workers who had a 90% or greater approval rating. The questionnaire was administered using SurveyGizmo [30]. Participants were each compensated $1.

We recruited approximately 100 participants for each study condition, for a total of 1300 participants. Because participants were randomly assigned to a study condition when beginning the questionnaire, and because not everyone completed the questionnaire, some conditions received slightly more than 100 responses and some received fewer. We removed responses that were incomplete and responses from participants who completed the survey from outside the United States (as determined by SurveyGizmo's IP-based geolocation), leaving us with 1281 total responses.

Procedure

All participants completed an online questionnaire (mean completion time: 6.33 minutes, SD = 5.05): they first read a description and watched one of two video scenarios depicting an actress interacting with Google Glass at a bus stop. Participants then completed a follow-up questionnaire pertaining to their overall impressions of the interaction.

There were four experiments in total, each with 2-4 conditions (see Table 1), for a total of 13 conditions. Participants were randomly assigned to one condition.

Figure 2. In Video 1, the actress walks to a bus stop using a white cane and dark sunglasses to indicate that she has a disability. Video 2 presented an identical interaction scenario, but without the actress's white cane and sunglasses.

Video Scenarios

Two videos, each 50 seconds in length, were used in this study (Figure 1). The videos depicted identical scenes of an actress walking to a bus stop, standing at the bus stop, and interacting with a Google Glass heads-up display. The two videos showed the same actress, scene, and interaction, but were designed to highlight or obscure the actress's potential disability. Video 1 showed the actress wearing Glass with sunglasses and using a white cane (Figure 2). Video 2 showed the actress wearing Google Glass with no accessories.

We chose to represent the actress with a visual impairment because participants would have some general understanding of the effects of this disability, and because we were able to effectively manipulate the actress's visual appearance. The bus stop setting was chosen as a recognizable public space. Google Glass was selected as the assistive device because it is an existing wearable computing device that was released as a consumer product, and has been used as a platform for assistive technology.

Participants in Experiment 1 were randomly assigned either Video 1 or Video 2. All participants in Experiments 2, 3, and 4 viewed Video 1 only.

Response Questionnaire

After watching the video, participants were asked to answer a series of questions about the video scenario. Each category of questions was placed on a separate page. The web browser back button was disabled in SurveyGizmo to discourage participants from changing their answers. Questions covered the following topics:

Reactions to the video scenario: Participants were first asked to respond in free-text to the prompt "Briefly describe what was going on in the video." This answer was used to verify that the participant watched the video, and to determine whether the participant had noticed the disability manipulation in Experiment 1.

Participants then provided responses to 13 questions on the following 7-point Likert scale: *Strongly Disagree, Disagree, Somewhat Disagree, Neither Agree nor Disagree, Somewhat Agree, Agree, Strongly Agree.* Questions were selected based on prior studies that have assessed the social acceptability of mobile and wearable computing devices [25, 26, 27]. Questions were presented to each participant in a random order. The categories and titles of the scale items were not presented to users, and are included here for clarity.

Statements about the interaction:

1. It looked awkward when this person was using the wearable computing device. **(Awkward)**
2. It looked normal when this person was using the wearable computing device. **(Normal)**
3. It was appropriate for this person to use the wearable computing device in this setting. **(Appropriate)**
4. It was rude for this person to use this wearable computing device. **(Rude)**
5. I felt uncomfortable watching this person use the wearable computing device. **(Uncomfortable)**
6. I would be distracted by this person if I were at the bus stop with them. **(Distracting)**

Statements about the user:

7. This person seemed independent. **(Independent)**
8. This person needed help. **(NeedHelp)**
9. This person needed the wearable computing device. **(NeedDevice)**
10. This person looked cool. **(Cool)**
11. This person looked nerdy. **(Nerdy)**

Statements about the device:

12. The wearable computing device seemed useful. **(Useful)**
13. The wearable computing device seemed unnecessary. **(Unnecessary)**

Participant background: These questions were presented on a page labelled "Demographic Questions". Questions were presented in a fixed order, and were as follows (response options presented in parentheses were applicable):

1. Were you previously familiar with the wearable computing device shown in this video? *(Yes, No)*
2. If so, have you used it before? *(Yes, No)*
3. How interested are you in using the wearable device? *(Strongly Uninterested, Uninterested, Somewhat Uninterested, Neither Interested or Uninterested, Somewhat Interested, Interested, Strongly Interested)*
4. What is your opinion on the wearable computing device?

We also asked participants to provide their gender, age, U.S. city and state, and level of education.

Effects of disability on device appropriateness: These questions explored whether participants' expressed opinions about the interaction may have been influenced by the actress's disability. This page began with the following statement: "We are interested in understanding to what extent it is acceptable to use a wearable computing device in public, and whether this acceptability changes if the wearer has a disability."

We asked participants "In the video you watched, did the person have a disability?" with options *Yes, No,* and *Not Sure.* We then asked "In general, does your opinion of the social acceptability of using a device like this change if the wearer has a disability?" with the options *Strong Negative Influence, Negative Influence, No Influence, Positive Influence,* and *Strong Positive Influence.* Finally, we asked participants for an open-ended response, "Please explain how this information would influence your opinion."

Experiments

We divided our analysis into four experiments in order to disambiguate how changing the video (in Experiment 1) and text descriptions (in Experiments 2 through 4) affected participants' attitudes. All participants answered the same set of questionnaires. Table 1 shows the explanatory text presented in each condition.

Experiments 2 through 4 used Video 1 only (Google Glass plus dark shades and a white cane). As these experiments compared varying levels of disclosure via text, choosing a single video that could plausibly represent either a disabled or non-disabled individual allowed us to more precisely control what information was disclosed to participants.

Experiment 1: Effects of Perceived Disability

This experiment explored whether participants perceived the differences in the actress's disability status based solely on the visual cues presented in each video. Participants in each condition saw the same explanatory text, but saw Video 1 (Google Glass plus dark shades and a white cane) in the *Visible Disability* condition, and Video 2 (Google Glass only) in the *No Visible Disability* condition.

Experiment 2: Disclosure of Disability Status

This experiment explored whether sharing more information about one's disability would affect participants' perceptions. Participants were shown the same video (Video 1: Google Glass plus dark shades and a white cane), but were either not told about the actress's disability (No Information), told that the actress had a disability (General Disability), or told that the actress was blind (Blindness).

Experiment 3: Disclosure of Assistive Purpose

In some situations, knowing that a device is being used to address a health concern or disability may make bystanders more sympathetic to the user. In this experiment, participants were shown the same video (Video 1) and told that a blind person was wearing the HMD, but were either given no information about the application being used (No Use Description), told that the device was being used by a blind person for an assistive purpose (General Assistance), that the device was being used by a blind person to check email

(Personal Use), or that the device was being used by a blind person to access an audio version of the bus schedule (Assistive Use).

Experiment 4: Disclosure of Video Recording

A major concern regarding the use of wearable computing devices in public is the risk of surreptitious video recording (especially photo or video capture). In this experiment, participants were either told that a blind person was using a wearable computing device which had a camera (Camera Only), told that the blind person was currently recording with the camera (Camera Recording), told that the camera was being used to record a personal photo album (Personal Use), or told that the camera was being used to recognize street signs (Assistive Use).

DATA ANALYSIS

We collected 1281 complete questionnaire responses from our participants. Data were analyzed using IBM SPSS Statistics version 22 on Mac OS X. Likert-scale responses were tested using the nonparametric Kruskal-Wallis test (except for Experiment 1, which used the Mann-Whitney U test as there were only two conditions). Pairwise comparisons were made using the Mann-Whitney U test with the Dunn-Bonferroni correction [7] as calculated by SPSS. We report only significant results in our paper for the purpose of readability.

Open-ended responses were analyzed using qualitative open and axial coding [4]. Our analysis focused on participants' justifications for their scale ratings. Two of the authors reviewed approximately half of the data together, and collaboratively developed the coding scheme. The two authors each coded the 1281 explanations separately, then resolved disagreements. Details of the codes, and inter-rater reliability using Cohen's kappa [3], are provided in subsequent sections.

FINDINGS

Table 2 presents mean ratings for each of the 13 scales across the 13 study conditions. Table 3 presents the significant main effects from each of the four experiments.

Participant Background

Participants ranged in age from 18 to 78 (mean=35.24, SD=11.34); 613 participants (47.8%) were female; 5 participants did not disclose their gender. When asked about prior experience with Google Glass, 291 participants were familiar with Glass (22.7%) and 10 (0.8%) had previously used Glass. When asked to rate their interest in using Glass (1=Strongly Uninterested, 7=Strongly Interested), participants provided a mean rating of 4.17 (SD=1.77).

Experiment 1: Effects of Perceived Disability

In Experiment 1, we tested whether altering our actress's appearance by adding a white cane and dark glasses successfully conveyed the actress's disability. We found that participants' perceptions of the actress's disability influenced their judgments of the social acceptability of her use of the HMD device.

E1: Effects of Perceived Disability
Visible Disability (E1-V, N=90), **No Visible Disability (E1-NV, N=101):** "The following video shows a person at a bus stop using a wearable computing device."
E2: Disclosure of Disability Status
No Information (E2-No, N=120): "The following video shows a person at a bus stop using a wearable computing device." **General Disability (E2-Dis, N=89):** "The following video shows a person with a disability at a bus stop using a wearable computing device." **Blindness (E2-Blind, N=89):** "The following video shows a person who is blind at a bus stop using a wearable computing device."
E3: Disclosure of Assistive Purpose
No Use Description (E3-NU, N=88): "The following video shows a person who is blind at a bus stop using a wearable computing device." **General Assistance (E3-Gen, N=92):** "The following video shows a person who is blind at a bus stop using a wearable computing device for assistance." **Personal Use: (E3-Mail, N=100)** "The following video shows a person who is blind at a bus stop using a wearable computing device to listen to an audio version of her email." **Assistive Use (E3-Bus, N=111):** "The following video shows a person who is blind at a bus stop using a wearable computing device to listen to an audio version of the bus schedule."
E4: Disclosure of Video Recording
Camera Only (E4-Cam, N=115): "The following video shows a person who is blind at a bus stop using a wearable computing device that contains a video camera." **Camera Recording (E4-Rec, N=95):** "The following video shows a person who is blind at a bus stop using a wearable computing device that is recording images using a video camera." **Personal Use (E4-Photo, N=102):** "The following video shows a person who is blind at a bus stop using a wearable computing device that that is recording images using a video camera for a personal photo album." **Assistive Use (E4-Sign, N=89)**: "The following video shows a person who is blind at a bus stop using a wearable computing device that is recording images using a video camera in order to recognize street signs."

Table 1. Text descriptions used in the study. In E1, participants were randomly assigned Video 1 or Video 2. In E2-E4, all participants were shown Video 1. Emphasis added for this paper only and was not shown to participants.

Awareness of Actress's Disability

Participants in this experiment were shown one of two videos: an actress walking to a bus stop and using a Google Glass device while wearing dark shades and carrying a white cane (Video 1), and a comparable video in which the actress performed the same actions but without the shades or white cane (Video 2). In pilot testing, we found that participants did not always notice that the actress was disabled, or were sometimes unsure whether the actress had a disability. In this experiment, we therefore included a question asking whether

	E1-V	E1-NV	E2-No	E2-Dis	E2-Blind	E3-NU	E3-Gen	E3-Mail	E3-Bus	E4-Cam	E4-Rec	E4-Photo	E4-Sign
Awkward	4.3 (1.8)	4.8 (1.6)	4.3 (1.8)	3.1 (1.8)	3.6 (1.8)	3.6 (1.7)	3.4 (1.8)	3.0 (1.7)	3.0 (1.6)	3.4 (1.8)	3.3 (1.9)	3.9 (1.8)	3.1 (1.7)
Normal	3.6 (1.7)	3.1 (1.5)	3.7 (1.7)	4.5 (1.8)	4.5 (1.6)	4.4 (1.7)	4.4 (1.4)	4.5 (1.6)	4.8 (1.6)	4.4 (1.6)	4.2 (1.8)	4.2 (1.7)	4.6 (1.6)
Appropriate	5.2 (1.5)	4.7 (1.5)	5.1 (1.4)	5.7 (1.4)	5.7 (1.3)	5.6 (1.4)	5.7 (1.1)	6.2 (1.0)	6.1 (0.9)	5.5 (1.2)	5.5 (1.6)	4.8 (1.6)	6.1 (1.1)
Rude	2.0 (1.3)	2.4 (1.3)	2.2 (1.4)	1.6 (1.1)	1.5 (0.7)	1.7 (1.0)	1.6 (0.9)	1.4 (0.7)	1.4 (0.7)	1.7 (1.1)	1.8 (1.2)	2.1 (1.2)	1.3 (0.6)
Uncomfortable	2.6 (1.8)	3.1 (1.7)	2.7 (1.7)	2.2 (1.7)	2.5 (1.7)	2.4 (1.6)	2.2 (1.4)	2.2 (1.5)	2.1 (1.4)	2.3 (1.5)	2.4 (1.6)	2.5 (1.5)	2.2 (1.5)
Distracting	3.8 (1.9)	4.6 (1.8)	4.1 (1.9)	3.1 (1.8)	3.4 (1.9)	3.2 (1.7)	3.3 (1.8)	3.2 (1.8)	2.9 (1.7)	3.7 (1.8)	3.6 (1.9)	3.8 (1.8)	3.3 (1.9)
Independent	5.5 (1.4)	5.2 (1.3)	5.7 (1.1)	6.1 (1.0)	6.1 (1.0)	6.0 (1.0)	5.8 (0.8)	6.2 (0.9)	6.1 (0.8)	6.1 (0.7)	6.1 (0.8)	5.8 (1.0)	6.2 (1.0)
NeedHelp	3.1 (1.7)	2.6 (1.3)	3.4 (1.7)	3.1 (1.6)	3.2 (1.3)	2.8 (1.5)	3.5 (1.6)	2.6 (1.7)	3.1 (1.6)	3.2 (1.5)	3.1 (1.6)	2.8 (1.3)	3.1 (1.6)
NeedDevice	4.4 (1.7)	3.1 (1.3)	4.6 (1.6)	5.0 (1.4)	4.9 (1.4)	4.8 (1.5)	5.0 (1.4)	5.3 (1.4)	5.6 (1.2)	4.6 (1.3)	4.4 (1.5)	4.0 (1.6)	5.4 (1.4)
Cool	3.6 (1.6)	3.1 (1.5)	3.7 (1.6)	4.4 (1.4)	4.3 (1.4)	4.1 (1.4)	4.5 (1.1)	4.4 (1.4)	4.5 (1.4)	4.3 (1.4)	4.5 (1.6)	4.2 (1.4)	4.5 (1.3)
Nerdy	3.6 (1.9)	4.5 (1.7)	3.5 (1.8)	2.6 (1.6)	2.7 (1.5)	2.9 (1.5)	2.8 (1.6)	2.8 (1.6)	2.7 (1.7)	2.7 (1.5)	2.6 (1.5)	2.8 (1.6)	2.5 (1.4)
Useful	5.1 (1.4)	4.5 (1.5)	5.2 (1.5)	5.6 (1.3)	5.3 (1.4)	5.3 (1.4)	5.2 (1.5)	6.4 (0.8)	6.2 (1.0)	5.2 (1.3)	5.0 (1.6)	4.7 (1.5)	5.7 (1.2)
Unnecessary	3.8 (1.8)	4.6 (1.6)	3.6 (1.8)	3.0 (1.7)	3.0 (1.6)	3.1 (1.7)	3.1 (1.7)	2.5 (1.4)	2.2 (1.3)	3.4 (1.6)	3.7 (1.7)	4.0 (1.6)	2.6 (1.5)

Table 2. Mean values and standard deviations for Likert scale surveys.

	E1 (U)	E1 (p<)	E1 (r)	E2 (X^2)	E2 (p<)	E3 (X^2)	E3 (p<)	E4 (X^2)	E4 (p<)
Awkward	5357	0.03	0.16	21.664	0.0001	8.042	0.045	11.648	0.009
Normal	3737.5	0.031	0.16	13.744	0.001	3.301	0.348	2.911	0.405
Appropriate	3538.5	0.007	0.20	18.75	0.0001	15.623	0.001	37.523	0.0001
Rude	5506	0.008	0.19	21.864	0.0001	7.433	0.059	30.809	0.0001
Uncomfortable	5427	0.017	0.17	12.749	0.002	3.686	0.297	4.699	0.195
Distracting	5634	0.004	0.21	14.664	0.001	3.61	0.307	4.612	0.202
Independent	3720.5	0.023	0.16	16.08	0.0001	15.572	0.001	8.292	0.04
NeedHelp	3868.5	0.063	0.13	1.574	0.455	20.56	0.0001	3.96	0.266
NeedDevice	2433.5	0.0001	0.41	2.556	0.279	17.406	0.001	45.201	0.0001
Cool	3815.5	0.052	0.14	11.734	0.003	5.171	0.16	3.505	0.32
Nerdy	5736	0.002	0.23	16.047	0.0001	2.026	0.567	1.924	0.588
Useful	3543	0.007	0.19	5.612	0.06	61.874	0.0001	21.711	0.0001
Unnecessary	5646	0.003	0.21	8.73	0.013	23.495	0.0001	36.078	0.0001

Table 3. Test scores and p-values for the 4 experiments. For Experiment 1, effect size is included, calculated as Z/sqrt(N). Shaded cells indicate attributes with a significant main effect (p<.05) for that experiment.

the actress portrayed in the video was disabled. We placed this question at the end of the questionnaire so that it did not influence the participants' other responses.

Of the 90 participants who were shown Video 1, 60 (66.7%) said the actress was disabled, 24 (26.7%) were unsure, and 6 (6.7%) said the actress was not disabled. For the 101 participants who saw Video 2, none said the actress was disabled, 39 (38.6%) were unsure, and 62 (61.4%) said the actress was not disabled. A Chi-square test shows that this difference in response was statistically significant between the two video conditions: X^2 (2, N = 191) = 109.42, p < .01.

A relatively large number of participants who saw Video 1 were uncertain about whether the actress was blind. In examining comments, it seems clear that some participants were unsure whether the actress herself was "really" blind, while other participants expressed confusion about why someone who was visually impaired would wear an HMD.

Another way to measure participants' judgments of the actress's disability is to analyze their free text descriptions of the scenario, which were collected directly after participants had viewed the video. Of the 90 participants who saw Video 1, 38 (42.2%) mentioned blindness in their description, 5 (5.5%) mentioned a cane or walking stick, and 47 did not mention either of those things. Some participants expressed uncertainty because, while the actress appeared to be blind, she also seemed to be using a device with a screen: *"I'm not sure. At first, it looked like a blind woman was wearing the device, but then it looked like she may have been viewing pictures through the glass. It appeared as though she was changing screens by swiping the edge of the glasses."*

While not all participants who saw Video 1 were certain that the actress was blind, we do not consider this a failed manipulation. Prior studies of mobile device use by people with disabilities have shown that bystanders may not understand that a person with a disability can use a given device, or may misunderstand how the device is used [14, 29]. Thus, this ambiguity may be an inherent effect when someone with little experience with accessible technology encounters someone using AT.

Effect of Disability on Social Acceptability

We compared participants' responses on our 13 scale questions across the two video conditions. We found a main effect of the video shown on 11 of our 13 scales: participants who saw Video 1, with the actress who appeared blind, considered the interaction less awkward, more normal, more appropriate, less rude, less uncomfortable, and less distracting; considered the actress more independent, less nerdy, and thought she needed the device more; and considered the device more useful and less unnecessary (see Table 3 for p-values and effect sizes).

As noted in the previous section, participants in Experiment 1 were never definitively told whether the actress portrayed a person with a disability. Thus, the difference in responses could be due to either the actress's presumed disability, or due to some other, incidental difference in the video. We can confirm that this result is in fact influenced by the actress's perceived disability by determining whether participants who answered that they believed the actress to be disabled rated the interaction differently. To explore this, we conducted a Kruskal-Wallis test, including all participants in Experiment 1, to determine whether their disability determination (yes, no, or not sure) affected their ratings.

Participants' assessment of the actress's disability (yes, no, not sure) had a significant main effect on 12 of the 13 scales (all but Cool). Participants who thought the actress was disabled had a more positive view of the interaction, the actress, and the device. Table 4 summarizes the findings from this analysis. These findings confirm that, when the onlooker believed that the user of the wearable computing device had a disability, they considered the interaction to be more acceptable and the device to be more useful.

Yes vs. Not Sure: Yes was less awkward†, more normal‡, more appropriate‡, less rude‡, less uncomfortable‡, more independent‡, needed device more‡, more useful‡, less unnecessary‡
Yes vs. No: Yes was more normal†, more appropriate‡, less rude‡, less distracting†, less uncomfortable‡, more independent‡, less nerdy†, needed device more‡, needed help more†, more useful‡, less unnecessary‡
Not Sure vs. No: Not Sure needed device more†

Table 4. In Experiment 1, participants' assessment of the actress's disability affected their assessment of the interaction. Participants considered the interaction more positively when they believed the actress had a disability. † denotes significance at p<.05; ‡ p<.01.

Experiment 2: Disclosure of Disability Status

This experiment focused on how the amount of information presented about the user of the wearable device would influence participants' judgments. This experiment was motivated by two questions. First, would participants' perceptions be influenced by the actress's disability when conveyed through a textual description, rather than changing the video? Second, would participants' judgments be further influenced by knowing additional detail about the actress's disability status (e.g., specifically learning that the actress was blind?).

Overall, as in Experiment 1, we found that participants considered the interaction more acceptable if they believed that the actress had a disability. However, there was little evidence that describing the actress's disability (general disability versus a specific disability) differently affected participants' assessments.

When the actress was described as either blind or disabled, in comparison with when the actress's disability was not described, participants considered the interaction significantly less awkward, more normal, more appropriate, less rude, and less distracting; considered the actress more independent, more cool, and less nerdy; and considered the device less unnecessary. Table 5 provides details of these significant pairwise comparisons.

As in Experiment 1, we see that knowing an individual's disability status influences participants' judgments about a user's interaction with a wearable computer. Unlike Experiment 1, this experiment shows that this effect holds when the visual presentation of the user remains the same yet some other indication of the user's disability status is expressed (e.g., textual disclosure of disability). However, we did not see consistent differences between different levels of disclosure of disability status (describing the actress as a person "with a disability' vs. a person "who is blind" – see Table 1). This may be because our actress appeared visually impaired, and most study participants would assume that she was visually impaired without being given that information explicitly.

Experiment 3: Disclosure of Assistive Purpose

Our prior experiments support the hypothesis that knowing that a person has a disability affects participants' judgments of the appropriateness of using a wearable computing device in public. In Experiment 3, we were interested in exploring whether conveying more information about how a device is being used would influence perceptions. Specifically, would participants be more positive about the device if the participants knew how the device was being used? Would this evaluation differ if the user was using the device for an explicit accessibility purpose (such as navigation) rather than a more superfluous use, such as checking email?

Overall, providing more detail about how the device was being used had a positive influence on participants' assessments. Participants rated the device more positively when its use was described, both in the assistive use case (looking up a bus stop) and in the personal use case (reading email). The device was rated less positively when no specific use was described. Significant pairwise comparisons are shown in Table 5. There was a significant effect of experimental condition on awkwardness (p<.05), but no significant pairwise interactions after post-hoc correction.

The results of this experiment show that participants rated the device as more useful when its purpose was known, but that the specific use did not strongly affect participants' perceptions of the acceptability of its use.

Experiment 4: Disclosure of Video Recording

One growing concern related to the public use of wearable computing devices such as Google Glass is their potential for surreptitious video recording. In this experiment, we explored the severity of this effect in the context of accessibility, to determine whether the assistive use of a device makes a difference in participants' perceptions.

Our first question was whether describing the presence of the camera, or the fact that it was recording, would affect participants' assessments. The video used in the experiments shows Google Glass with its front-facing camera lens (Figure 1). We were interested in whether describing use of the device camera would affect participants' impressions. Experiment 3 demonstrated that participants rated device interactions more positively when additional detail was provided about how the device was being used.

Our findings in Experiment 4 show that this relationship holds true when conveying the assistive nature of the device's video recording. When the scenario was described as following a specific assistive purpose, participants rated the interaction more positively, but noted that the actress needed the device more. The interaction was rated more negatively when the device was described as being used for a personal purpose, or when the use was not specified. Significant pairwise comparisons are shown in Table 5. We found no significant differences regarding whether the camera was described as recording or not.

Overall, participants in Experiment 4 reacted negatively to the use of a camera for a non-assistive purpose. While Experiment 3 did not show a significant effect of the device use on participants' judgments, adding the recording scenarios seemed to further polarize participants' opinions.

E2: Disclosure of Disability Status
General Disability vs. No Information: General Disability was less awkward‡, more normal‡, more appropriate‡, less rude‡, less uncomfortable‡, less distracting‡, more independent‡, more cool‡, less nerdy‡, less unnecessary†
Blindness vs. No Information: Blindness was less awkward†, more normal‡, more appropriate‡, less rude‡, less distracting†, more independent‡, more cool†, less nerdy‡, less unnecessary†
E3: Disclosure of Assistive Purpose
Assistive Use vs. General Assistance: Assistive Use was more appropriate†, more independent†, needed device more‡, more useful‡, less unnecessary‡
Assistive Use vs. No Use Description: Assistive Use was more useful‡, less unnecessary‡, needed device more‡
Personal Use vs. General Assistance: Personal Use was more appropriate†, more independent‡, needed help less‡, more useful‡
Personal Use vs. No Use Description: Personal Use was more appropriate†, more useful‡
E4: Disclosure of Video Recording
Assistive Use vs. Camera Only: Assistive Use was more appropriate‡, less rude‡, needed device more‡, less unnecessary‡
Assistive Use vs. Camera Recording: Assistive Use was more appropriate†, less rude†, needed device more‡, more useful†, less unnecessary‡
Assistive Use vs. Personal Use: Assistive Use was less awkward‡, more appropriate‡, less rude‡, more independent†, needed device more‡, more useful‡, less unnecessary‡
Camera Recording vs. Personal Use: Camera Recording was more appropriate‡, less rude†
Camera Only vs. Personal Use: Camera Only was more appropriate†, needed device more†, less unnecessary†

Table 5. Significant pairwise comparisons from Experiments 2 through 4. † denotes significance at $p<.05$; ‡ $p<.01$.

Attitudes About Wearable Computing Use and Disability

After providing ratings for the video scenario, we asked participants whether it was more or less acceptable for a person to use a wearable computing device in public if they had a disability. For this section, we aggregate our findings across all four experiments.

We asked participants if knowing that a person had a disability would affect their judgment of the social acceptability of using that device. 524 participants (40.9%) stated that this information would have a positive influence, and 242 (18.9%) stated that it would have a strong positive influence. 500 participants (39%) said their judgment would be unaffected by this information. Only eight participants (0.8%) said that it would have a negative influence on their judgment, and seven participants (0.5%) said that it would have a strong negative influence.

We performed qualitative coding of the primary themes present in participants' justifications:

Using the device was more acceptable for a person with a disability because it helped them (654, 51%, κ=0.75). Many participants commented on how the HMD could potentially help a person with a disability. Participants stated that using the device in public would be acceptable if it was helping a person with a disability act more independently: *"if it is helping someone with a disability become more independent, I think it is a great idea."*

Others suggested that some people with disabilities might have a need to use the device: *"I would be less likely to form a negative opinion of a disabled person wearing such a device, because I would likely believe that it was helpful or necessary for them. A non-disabled person using such a device in public is more likely to seem obnoxious."*

Comparisons to other forms of AT (28, 2.2%, κ=0.82). Participants also justified the acceptability of wearable AT based on existing policies related to accessibility and use of other types of assistive technologies: *"I think if it is something that helps the person, than [sic] it should be more accepted. Think of a seeing eye dog in a grocery store or restaurant. It is frowned upon for many people but accepted for people with disabilities, as it should be."*

Using the device was less acceptable for a person without a disability because it was not needed (118, 9.2%, κ=0.61). In contrast to describing the positive effects of HMDs for people with disabilities, some participants pointed out that it would be unacceptable to use this type of device in public without a legitimate need. Individuals who didn't need to use the device might be using it to show off or isolate themselves from social interactions: *"Someone with a disability may need the device, unlike someone who just has it because they want to be technologically hip. If someone is using the device because they need it I won't judge them, I'll actually think that it's cool that they found something that can really help them be more independent."*

Using the device could cause problems for a person with a disability due to lack of situational awareness (8, 0.6%, κ=0.62). Some participants were less positive about the potential for HMDs to help individuals with disabilities. One reason for this negative opinion was to suggest that a person with a disability might be especially vulnerable to distractions from technology: *"I think if person already has [a disability] they need less distraction and [a] wearable computing device in public can be more harmful."*

Using an HMD would not be beneficial to a blind person because the interface is primarily visual (33, 2.6%, κ=0.76). Our video scenarios showed a person with a vision impairment using a head-mounted wearable computing device. Some participants were confused about the presence of the visual display on Google Glass, even though the screen was not active during our video scenario. Participants wondered why someone who is blind would be using Google Glass, sometimes incorrectly assuming that the device could only provide visual feedback: *"The wearable device is purely visual and the person was blind, so it made no sense."* Other participants questioned whether the actress was truly visually impaired, or whether she might have some vision.

Concerns about recording (34, 2.7%, κ=0.68). An additional theme that appeared in several explanations was concern about nefarious use of the HMD, particularly around recording. A number of participants explicitly raised questions about the possibility of Glass to record audio or video, or to otherwise invade individuals' privacy: *"It really depends how the device is used. If the device is helping a visually disabled person navigate the surroundings, then I think it's OK. If that same person was using the device to just record everything, then it's probably not OK."*

In some cases, the fact that the user might be disabled made this less of a concern: *"You figure a handicapped person isn't going to use a device to secretly record you and put it on Youtube, you figure they have more of a need to have special devices."*

On the other hand, one participant suggested that the risk of privacy invasion could be higher if the user does not have complete access to the device: *"It could be negative in this case because the blind person does not know what she is recording. She didn't appear to be filming her family, so why would she want video of people she didn't know?"*

DISCUSSION

Overall, we found strong and consistent effects regarding the interaction between knowledge of a wearable computing user's disability status and judgments regarding the social acceptability of the use of the wearable computer in public. In the case of a non-disabled user, participants frequently expressed negative opinions about device use: the device was considered to be unnecessary and the interaction was deemed more awkward and rude. When informed of the user's disability, participants generally rated the interactions to be less awkward and considered the user to be less rude.

This interaction between disability and social acceptability held regardless of whether the participant was told that the user had a disability or whether it was assumed based on her appearance. In real life, an individual may not know whether another person has a disability, and our participants sometimes raised questions about this when the actress's disability status was unclear. That our findings were consistent across both appearance manipulations and description manipulations suggests that this effect may hold regardless of how the user's disability is identified.

We also found that disclosing the use of the AT resulted in more positive assessments from bystanders. Participants rated the interaction more positively when the use of the device was described. The exception to this in our current study was when we described the HMD as storing photos for a personal photo album; participants seemed to think that this use was superfluous, especially because the actress was described as blind and thus might not need a photo album.

In general, our participants rated both the actress and the device more positively when the actress was using the device for an assistive purpose. This overall positive tendency led to some counter-intuitive trends in our ratings. For example, participants rated the interaction as more "normal" when they believed that the actress was disabled. This is surprising because we can presume that, for most people, seeing a person with a disability is less common than seeing someone without a disability. There may be several explanations for this outcome: it may be that participants considered it normal for a person with a disability to use AT in public, whereas a non-disabled person may be considered abnormal for adopting a wearable computing device, or participants may simply have a more positive impression of the actress overall when she is identified as disabled because of some halo effect. Likewise, participants rated the actress as more "independent" when she was described as being disabled: this may be because the concept of independence is particularly salient when considering a person with a disability, or because a non-disabled person may be considered dependent if they choose to use and wear an unusual piece of technology. Exploring the motivations for these judgments in more detail presents an exciting opportunity for future work.

Implications for Wearable Computing Design and Policy

While our study only explored a single interaction scenario, our findings show a clear and consistent relationship between disclosure about the user's disability or AT use and social acceptability. While our findings cannot generalize to all forms of on-body computing, this relationship between disclosure and acceptance has implications for considering how we design both assistive and non-assistive wearable computing devices, and how to set proper policy for using such devices in public settings.

Prior studies have demonstrated that people with disabilities are often concerned about drawing attention to themselves [14, 29]. These individuals often prefer to use the same devices as everyone else, in part due to a desire to blend in [14]. However, in our study, bystanders were more positive about the actress when they were aware that she was using AT. This finding suggests that, in some cases, a device that looks like an assistive device may be more socially accepted than a device that does not appear to be assistive. This effect also appears in existing forms of AT: for example, service dogs can often be identified by their distinctive harness, and it is less likely that someone will be questioned about a dog that appears to be a service dog. Thus, an AT user may sometimes wish to hide the assistive nature of their device in order to blend in, but may need to highlight the assistive function of their device in situations where use of the device might otherwise be considered inappropriate. There may be value in providing users with direct control of this disclosure through physical design features, so that the device could appear assistive at times and appear hidden or as a mainstream device at other times.

In considering policy surrounding the use of wearable AT devices in public spaces, a relevant finding from our study is that bystanders had a more positive attitude about a device when they knew it was being used for an assistive purpose. However, this desire of bystanders to understand the assistive use may directly conflict with the user's desire for privacy. Some current policies regarding service animals and other AT devices illustrate the tensions around needing to know that a device is being used as an accommodation while maintaining the user's privacy. For example, in the U.S., it is permitted to ask a person whether their service animal performs an assistive function, but not to ask what that function is. Some of our participants noted that people with disabilities may need special privileges for using technology, just as they currently have special privileges when bringing service animals in public places, while others expressed concern that they did not know how or why the device was being used. Enabling people with disabilities to use new forms of AT in public while maintaining their privacy may involve a combination of policies and social norms, along with changes to the AT itself or to other technical infrastructure (e.g., forcing devices to stop recording in public spaces, or using guaranteed privacy-preserving algorithms when capturing images in public).

LIMITATIONS AND FUTURE WORK

This study explored bystanders' attitudes about the public use of Google Glass in both assistive and non-assistive use cases. Through four experiments, we demonstrated how these attitudes change based on the user's disability status and the assistive purpose of the device. Here, we note study limitations that we plan to address in future research.

Our study respondents did not directly participate in the social interaction, but only viewed a video scenario. We were also only able to measure participants' self-reported attitudes. Conducting a study in which participants were more personally engaged might reveal different tensions, and might allow us to measure both explicit attitudes and implicit behavior such as visual attention.

We chose to focus on a single device (Google Glass) and a single disability (blindness). This allowed us to collect a large number of responses, and to observe effects related to how this information was disclosed. However, it would be interesting to explore whether participants' attitudes differed across different disabilities, technology form factors, or demographic factors such as age and gender. Furthermore, we only included participants from the United States. As attitudes about wearable computing usage and disability vary widely across the world, it would be valuable to reproduce this study in other countries.

Finally, the present study used multiple experiments to more precisely control information disclosed to the participants. However, it is clear that there are interactions between these factors – for example, a wearable device that records video may be considered generally unacceptable in public, but may be accepted if the device is needed for a medical purpose. In designing the study, we found it difficult to explore these interactions without including confounds. However, future studies may focus more directly on the interactions between these factors.

CONCLUSION

HMDs and other wearable computing devices present significant potential for providing assistance to individuals with disabilities. However, these devices raise questions of social acceptability when used in public spaces. Our study revealed a consistent effect of disability on the perceived acceptability of HMD use: use of the HMD was considered to be more acceptable if the user had a disability or if the device was used for assistive purposes. These findings offer insight for the design of HMDs for assistive scenarios, and may inform policy regarding the appropriate use of such devices in public settings.

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